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CRITICAL PATH METHOD NETWORKS AND THEIR USE IN CLAIMS' ANALYSIS

BY

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A REPORT PRESENTED TO THE GRADUATE COMMITTEE OF THE DEPARTMENT OF CIVIL ENGINEERING IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF ENGINEERING

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To Polly

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CHAPTER I

INTRODUCTION

1.1 Scheduling

Throughout history man has found it beneficial to schedule his daily activities. This has allowed him to organize his days so that he can get the most done in the shortest period of time. The necessity for scheduling was carried over into man's places of business, including the construction industry. As modern living became more complicated it was necessary to develop better methods for scheduling work activities.

Construction scheduling is not a new concept since man has been planning complicated projects for many years. The concept of someone having to plan out labor, tools, material, and equipment to do a job in some sort of sequence has always been around. However, not until the development of network diagramming techniques, which have the ability to show activity relationships, did the scheduling of construction projects receive any serious attention. This increased use of network scheduling as a planning and coordinating tool for construction projects has lead to legal definitions of the participant's rights, responsibilities, and liabilities.

The primary use of network schedules has normally been for the planning and scheduling of construction projects. A network schedule can be used to plan and schedule project resources. This helps in the identification of those resources required and when they are needed in order to complete the project within the allotted time. More recently, network schedules have been used to control resource expenditures during construction and to analyze construction claims involving time following the completion of a job.

1.2 Definition of Basic Terms

The following terms will be important to the reader to understand when dealing with critical path method networks:

1. Activity - an individual job, task, or operation which must be completed in order to finish the project.

2. Float - the amount of time an activity can be delayed without delaying subsequent activities.

3. Critical Path - the longest continuous performance path through the network used to determine the shortest possible duration for the project.

4. Critical Activity - an activity along the critical path; an activity with no float.

5. CPM schedule - a network diagram employing the critical path method to schedule project activities. Also referred to as a CPM network.

1.3 Gantt Charts

During World War I, Henry L. Gantt developed a display for production control which was basically a bar chart upon which specific time points were indicated. The Gantt chart has proven to be one of the most direct and easily understood methods for planning a project. Although originally developed for industrial trades the Gantt chart eventually became an acceptable scheduling technique for construction work because it depicted the activities to be done and made it easier to list the resources required to accomplish these activities. Projects were controlled by marking off the work completed and by observing the amount of progress as compared to the original schedule (1:8).

Gantt charts were initially used because of their simplicity and ability to graphically show the timeframe within which activities had to occur. However, this form of scheduling had some definite disadvantages:

1. It only vaguely demonstrated the logical sequences and interdependencies of the job activities.

2. The relationships of the work activities, the level of detail and the beginning, or start time of activities on the bar chart were usually in the mind of the person preparing the bar chart and were often open to interpretation (for example, a mechanical subcontractor's work could be shown as one long bar from the start of the project to its completion, even though many smaller activities may have been involved).

3. The Gantt chart represented job activities as independent, to be performed at any time, without indicating the logical predecessor activities which had to be at some stage of required completion prior to the start of any subsequent activities.

4. There was no indication of the latest time when non-critical activities had to be completed.

5. The Gantt chart did not give a critical list of activities that had to be completed on time lest the project be delayed.

6. The Gantt chart did not relate resource availability and could not help management determine where and how to predict problem areas or the impact of earlier problems (8:13).

Since the Gantt chart, hereinafter referred to as a bar chart, does not indicate critical activities and their relationships, it has been widely held that bar charts are not acceptable for determining the impact of delays or disruptions.

1.4 Network Diagrams

As time progressed, it became apparent that bar charts were not suitable for very large or complex projects since they only indicated the relative durations of each activity and not their relationship with other activities in the project. A level of breakdown was needed so that every activity had to be complete before the next one could start. When certain activities could be start before another was complete further breakdown was necessary. This requirement led to the introduction of restraints on bar charts which

allowed for more detailed analyses. However, this still was not detailed enough to handle very large or involved projects.

In 1956, the complexities of construction work for chemical plants led the E.I. duPont de Nemours Company to search for better ways to schedule work activities. A team, with the objective of improving the planning and scheduling of construction, was formed with Morgan Walker of duPont and James E. Kelley, Jr. of Remington Rand Corporation directing the work. They developed a rational, disciplined and simple method for describing a project. However, this method required a greater capacity for computation than the traditional methods of scheduling. This led to their union with Dr. John W Mauchly of UNIVAC to adapt the method to a digital computer. The resulting method of networking has been called the Critical Path Method (CPM) (1:4-7).

Later on, modifications and improvements were made to the original CPM method developed by Walker and Kelley. Separately, the Navy developed the "Program Evaluation Research Task" (PERT) method which incorporated the use of probabilities into the CPM technique. CPM and PERT were developed independently, but both made use of the network as the graphical model and identified the longest, or critical, path. The major difference was that CPM assumed that the duration

of each activity could be established with reasonable accuracy, while PERT assumed that the duration times could have fairly large variations. In both cases the solution of the network follows the same pattern once the durations (and probabilities for PERT networks) have been established.

Other variations of CPM and PERT have been developed, usually due to the special requirements of particular situations. Despite the wide variety of network methods, there are only a few types regularly used in the construction industry. For example, PERT charts are usually encountered in the field of research and development, where activity durations are not very certain, rather than in construction, where durations can be ascertained with reasonable confidence. Basically however, each method relies on the development of a network of activities with the longest path being identified to determine the shortest possible duration for the job. This report will concentrate on the basic CPM network since the applications discussed can usually be applied to other network models.

1.5 Use of the Critical Path Method (CPM)

Making decisions is the prime function of management. It requires the use of all available

information. In order for a CPM network to be used to its full advantage the network diagram must be constructed in fine detail. The finer the detail, the better will be the information imparted by the network and consequently the better the decisions will be resulting from the use of the network.

CPM networks have been used by many construction firms over the last 20 years. Some have used it more successfully than others. Many have started out using it with the intention of employing it throughout a contract. However, when the original CPM network required major adjustments, it tended to be abandoned and essentially never used again.

CPM allows for the presentation of ideas and plans in a logical manner. As such, the CPM network is only as good as the contractor's plan. If there is a poor plan to begin with, then the use of CPM will only tend to emphasize any problems. The CPM network diagram graphically portrays the logical interrelationships of the various components of the project. The basic mathematical concepts are the same for each variation of a CPM network no matter how different they appear to be. In order to be consistent here, one basic approach, that of the arrow diagram, will be used. The mechanics will be outlined to provide a foundation upon which to examine the use of a CPM network.

1.6 Using a CPM Network Schedule

The focus of this report is primarily centered around the use of CPM network schedules in the analysis of contractors' claims for additional compensation as a result of impacts caused by the owner. The second chapter will examine the various uses of a CPM network on a construction project. The third chapter will outline the basic mechanics of CPM including how a network is put together and how it is used and updated throughout the life of the project. This hopefully will give the reader an idea of what a CPM network is and what it is expected to do for the person who employs it. In Chapter Four the methods of establishing a network so that it will stand up in a court of law will be outlined. Chapter Five will concentrate more fully on the potential uses of a CPM network in analyzing a claim including the general methods of manipulating the network to make it useful to an impartial third party. Chapter Six will outline some practical aspects and applications of CPM network analysis for Navy construction contracts as well as emphasizing various difficulties and points to remember about the entire process. Finally, Chapter Seven will offer some conclusions and recommendations.

CHAPTER II

CPM USE IN CONSTRUCTION

2.1 Activity Planning

When construction projects were not so complex, it was relatively simple for a contractor to plan the job in his head with relatively little paperwork. However, as projects began to grow in size and complexity due to advancing technology, it became impossible to contain the interrelationships of all the operations of a project in one person's mind. Complexity generated the need for specialization, which in turn led to the increasing probability of miscommunication between these various specialists. Only by detailed planning did it become feasible to combine each of the specialized areas into one project.

CPM has proven to be an effective tool for planning and scheduling work, directing work, and measuring and controlling work. It permits the work schedule to be understood and thought out well in advance for material procurement, equipment availability, and to some extent manloading. Preparing the network diagram forces the thinking through of the job from start to finish, thus permitting early identification of potential problem areas on the project. The CPM network diagram shows how the planner

sees the job logic, often revealing if he knows what the job is about and how much he understands about the construction process (2:12).

CPM is used in three major areas during the life of a construction project. These are the areas of planning, scheduling, and controlling. Planning includes the development of the initial plan and a decision on the best approach based on a comparison of various alternatives. This includes the identification of all work activities and their dependencies. In other words how and in what order the work will be done. Scheduling involves the determination of activity durations and assignment of resources. This includes resource requirements and allocations based on the various possible approaches taken by the contractor. Scheduling determines when the work can be done based on any resource limitations. Controlling includes the decision making process based on actual performance, alternatives, trends, material supply and expediting, change orders, and changed conditions.

2.2 Putting a Network Together

When a new project is undertaken it is necessary to visualize all of the activities of the project in order to be able to effectively plan their completion. Once the activities have been identified they must be

placed in their proper sequence. This determines the logic of the network, i.e. the order in which the activities are to be completed. Once the logic is determined, a duration for each activity is determined and assigned to that activity. A calendar can then be attached and resources, such as money, equipment, and materials can be allocated to each operation. The planner should then be able to achieve the most economical means for completing the entire project (1:6-7).

The heart of the network concept is a graphic portrayal of the plan for executing the project. The network plan diagrammatically illustrates all interdependencies of the project activities. It is used as a basis for estimating activity durations, scheduling the total project time, and establishing priorities. In addition, it can be used for integrating time, cost, and available resources such as manpower and equipment. Although the calculations can be done manually, a computer system is invariably used to generate schedule dates, slack times, etc..

There are various ways that a network can be put together to meet the project end date. Although the project duration is rigidly fixed by the critical path, the network does not provide a basis for scheduling the activities not on the critical path. A good schedule usually exists between the limits of having every

activity starting at the earliest time possible and having every activity starting at the latest time possible. Having all activities start at their earliest possible times tends to result in a very high rate of expenditure at the beginning of the project. The advantage of this is that there is some play, or float, in the noncritical activities in case something goes wrong. The disadvantage is that the contractor's capital is tied up over a longer period of time, resulting in higher interest costs. The owner also has little time to incorporate changes without suffering an increase in cost. Employing the latest starts results in activities losing their safety margins, the float times, which means that those items initially identified as noncritical become critical, if delayed, and result in a later completion date for the project. In addition, neither method does anything to minimize the extreme rises and falls in the manpower and equipment requirements during the life of the project.

A better method is for the planner to determine a schedule that will minimize the fluctuations in the labor force throughout the project and that will provide flexibility in the schedule to meet unexpected conditions. This requires that he consider manpower, equipment, cash flow, and local project conditions in

addition to the straight mathematical considerations when drawing up the project schedule (1:23-25).

2.3 Adding Costs to the Network

When the cost requirements, both direct and indirect, are added to each activity on the network the contractor is provided with integrated information on the scheduled activities and their related costs. A cost integrated schedule:

1. provides a basis for developing, by activity, a time and cost budget,

2. provides a basis for progress payments,

3. forecasts potential cost overruns related to schedule slippages so that corrective action can be initiated before trouble develops, and

4. provides information for determining the best cost/time tradeoffs. (Basic assumption is that there is a relationship between the dollar cost and the expected completion time for each activity.)

Project cost/time optimization techniques are one of the most powerful planning tools available through CPM. Indirect and direct cost data can be established relating to each activity time so that the most economical project schedule can be established. Normally, a time and cost are developed for each activity. The critical path is then adjusted by selecting the time that minimizes the total project cost. CPM can help to predict the need for cash, to report money spent versus work accomplished, to verify

subcontractor bills and to determine money that is due the contractor (3:58-69).

2.4 Controlling

The value of a plan lies in its implementation. The project is kept on schedule and within the budget through the control function which is as important as the original plan. Planning for the sake of planning is of relatively little use. During the construction process progress is measured against the planned targets of the network and schedule or cost deviations are implemented. If the corrective action cannot bring the project within the limits required then the plan must be modified. This use of the control function assists in the timely completion of the project with the maximum utilization of resources and capital and the minimum amount of risk.

Once a project has been planned and scheduled it becomes management's responsibility to control its progress and cost so that the project objectives are obtained. This is achieved by monitoring actual progress and resource expenditures, comparing these with the planned progress and resource expenditures and, when necessary, taking the corrective action necessary to bring the project back on schedule. This constantly changing situation makes it imperative that

the schedule be updated regularly. If not, the contractor runs the risk of the project controlling him through crisis management rather than having him control the project.

The first course of action in regaining a desired performance position is through the manipulation of the available resources within the current network. This redistribution of manpower and equipment may produce new characteristics in the project plan and may produce new critical paths. Once the network is analyzed, rescheduled, and costed, the contractor must decide if this is acceptable. If not, other distributions of resources may be necessary. The control of the project requires not only the keeping of performance in accordance with the plan, but also the continual updating of the plan so that it always depicts the latest strategy.

Because of the unpredictable nature of construction, the time required for the completion of a project will most assuredly be changed from that originally planned. Factors which influence the time of completion include the weather, labor productivity, strikes, material delivery, and so on. Quite similarly, the costs for the project will usually be different from those originally estimated. Most factors cannot be eliminated but can be compensated for

by efficient management. Thus, it is necessary to have adequate feedback on progress and expenditures to be able to decide on the necessary compensatory action for any situation.

The control of any construction project requires adequate response to the changing conditions that affect it. Obtaining feedback is essential to management making any intelligent decisions. The project plan can only be correctly adjusted if sufficient information is provided. Measurement of actual achievement (feedback) through progress reports and its comparison with the original plan is essential.

Time and cost are two key objectives that determine the success or failure of a project. The final cost and time of completion cannot be determined or forecasted accurately until the project is substantially complete. The successful control of time and cost depend largely on how well scheduling and cost control techniques are employed as management tools of the owner. Good scheduling and cost control enable early detection of potential problems and allow management the time to take corrective action (5:53-84).

2.5 Use of Networks in Litigation

Bar charts have been used occasionally to provide evidence of delays. However, no dispute involving a

construction project with sophisticated scheduling was decided by the American legal system prior to 1966 (4:3).

In addition, there was little interest in schedule analysis to determine responsibility for delayed project completion prior to 1968. This was probably due to the fact that delays, or non-direct costs, were uncollectable in the federal sector until that point. The policy that had developed, termed the Rice Doctrine, was generated by several court cases. The changes clause of federal contracts, as interpreted by the courts, gave the government the right to take a reasonable time to make changes during contract performance. Any government delay to the contractor's performance of the unchanged work, over a reasonable period of time, was not considered a justifiable reason for recovery of additional monies due to extended performance time. The expenses for any delayed performance, as a result of the government's ordered delays, was absorbed by the contractor. This potential for delay due to possible changes was known to both parties during the bidding stage. However, in 1968 federal construction contract rules were altered to allow the contractor to recover the cost of unchanged work including any costs for delayed project completion. This had the effect of encouraging major

federal agencies to issue guides for using sophisticated scheduling techniques to measure the effects of change orders on the contractor's unchanged work.

Since that decision, the courts have begun to increasingly recognize the usefulness of network schedules in proving delay damages. However, the number of cases that have been decided using construction schedules as a basis have been few and far between. In addition, there has been no accumulation of cases or indexes which have been grouped together under "schedules" in legal dictionaries. This presents a problem to the person searching for information on construction schedule litigation since he has no organized method for finding what little information does exist. Contributing to this extreme lack of information is the fact that many construction disputes are arbitrated, which leaves little information for future cases.(4:4)

Besides the fact that there is little information on the results of construction disputes using construction schedules, there is very little uniformity in scheduling methods. There are differences in specification requirements and the degree of understanding and use of scheduling methods. It makes sense that schedules should be used in the litigation

process in the same manner in which they are used in the construction process. This would require a somewhat uniform understanding of scheduling requirements, which is a situation that currently does not exist in the construction industry. The result is that courts and boards have not always applied scheduling techniques in construction litigation in the same way that schedules are applied as planning tools in the construction industry. This occurs even though there is a fairly uniform acceptance of the industry definition of schedules by the courts.

Courts and boards have begun to realize the potential for using the critical path method to coordinate and schedule a construction project. "The United States District Court for the Western District of Missouri, in *Natkin and Company vs George A. Fuller Company*, observed that 'The Critical Path Method is a valuable tool on a complex job, saving time and money for owners and contractors.'"(4:67)

Although courts have generally accepted the construction industry definition of the critical path method they have not applied the technique to construction disputes in the same way as it is applied as a planning and scheduling tool. Many times the courts and boards have not taken the time to understand the basic foundations of scheduling. They have tended

to assume that a level of competence exists, which may or may not be true. Courts have tended to accept textbook definitions of the critical path method which, although technically correct, are many times too brief to provide an adequate background in network scheduling techniques. This hinders the courts or boards when it becomes necessary to apply a detailed analysis to resolve a complex construction scheduling dispute.

The courts have recognized the limitations of bar charts when compared to networks using the critical path method. They have recognized that the bar chart does not show the dependencies of activities on one another. Because of this, the use of bar charts alone to prove delays has had little success. In the event of a delay claim, the Army Corps of Engineers recommends changing a bar chart to a network system to allow for a CPM analysis even though there is no contract requirement for a CPM schedule.

Even though the use of bar charts alone is not a viable method, they can still be of use due to their inherent simplicity. In some cases it may be feasible and wise to use a bar chart to demonstrate a critical path analysis. The illustration of a CPM schedule in bar chart form may better show the effect of a delay on certain activities. When this is done, however, the

bar chart is used only to simplify the presentation of a complicated network analysis and not to replace it.

No matter which technique is used, the employment of a CPM schedule can usually be of assistance to the contractor in supporting claims for price adjustments and time extensions. They can also be used to aid the owner in the defense of claims and to justify the assessment of liquidated damages for late contract performance.

The law states that where both the owner and contractor contribute to the delay, neither can recover damages unless it can be clearly demonstrated what the division of responsibility is for the delay. Once sufficient evidence has been presented to allow for this division of responsibility, the court may then allocate the delay among the different parties. Bar charts cannot show the interrelationships between multiple causes of delay; however, the critical path method can and is thus much more apropos for delay claims.

CHAPTER III

PREPARING AND UPDATING A CPM NETWORK

3.1 Scheduling Basics

Construction schedules using CPM establish the sequential order in which the construction is to be completed. In order to accomplish this, the planner needs to have an intimate knowledge of construction methods together with an ability to visualize various work activities which have been outlined in the design documents. He must also be able to establish any interdependence between each of these activities. Once the planner has established a sequential order, resources, such as manpower, equipment, materials, etc., may be included for even greater control. The addition of these resources may even impact on the original sequence.

The compilation of a construction schedule can be an extremely intricate task since large construction projects can have thousands of activities which are interrelated in one way or another. The schedule produced will only be as good as the time invested and the knowledge of the scheduler. A schedule which is based on faulty logic or which contains unrealistic activity durations will be of limited use to the contractor. Many times a schedule is drawn up without

any thought to the many interrelated items. In addition, the use of subcontractors sometimes prevents the general contractor from knowing the full extent of the resources required.

Construction scheduling involves an effort by a contractor to look into the future in order to see what should happen during the life of a construction project. Since the expected rarely happens, it is likely that the schedule will rapidly become outdated. This requires the construction schedule be continually revised to reflect current conditions. If a schedule is not changed, it quickly loses its usefulness. Since a construction schedule is based on the best project information available, it must be altered when better information, based on newer data, is obtained.

3.2 Methods of Diagramming

There are three basic methods of constructing a logic diagram. These are activity on the arrow, event on the node, and activity on the node. The difference between these methods results from the placement of emphasis on activities or on events and from the location of these activities or events. An event represents the completion of an activity, or a point in time; it has no time duration. When the activity on arrow method is used, the emphasis is on the

description of the activity and is represented by the arrow between the nodes. This method is most often associated with the traditional CPM technique and is sometimes referred to as "I-J" networking because each activity is identified by the "I" node preceeding and "J" node succeeding it. In the event on the node method the emphasis is on the description of an event, which is a description of state, and the arrows connect the events. The latter method is more often associated with the PERT system of networking because of that system's emphasis on the attainment of events.

The third method of diagramming a network is termed activity on the node. Similar to "I-J" networking, this is an activity oriented system. However, this method lends itself to the representation of events as well as activities. Activity on the node networking is most often associated with the precedence method of diagramming. Precedence diagramming first appeared around 1964 in the "User's Manual" for an IBM 1440 Computer program. One of the principal authors of the technique was J. David Craig of the IBM Corporation.

As in the event on the node method, in precedence diagramming the arrows simply indicate the logic dependencies of the activities. The nodes, which represent the activities, are typically boxes which contain the activity number, the activity description,

etc.. Unlike the activity on arrow technique each activity has only one number, the "I" number, and is connected to succeeding activities from either its starting or finishing point to the next activity's starting or finishing point. This presents a start-finish sequence without having to break down each activity to eliminate overlap as is required in the "I-J" method. The precedence method allows activities to start before preceeding ones are finished through the use of "lag indicators" and is, thus, more flexible. In the "I-J" method there can be no overlap since preceeding activities must be completed before succeeding ones can start. However, both methods result in the development of a critical path of activities. Since the "I-J" method is the most common it will be emphasized throughout the remainder of this report. However, the techniques employed on "I-J" diagramming can easily be transferred to networks employing the precedence method.

3.3 Developing an "I-J" Network

In the "I-J" method, the tail of the arrow is the starting point of an activity. The head of the arrow represents its completion. The starting and ending points of an activity are known as nodes. The "I" node represents the beginning point of an activity and the

"J" node represents the ending point. In the logic diagram one activity's "J" node (activity completion) also represents the "I" node (activity beginning) for all immediately succeeding activities. The arrows simply indicate the flow of the work; they have no time significance.

The "I-J" method is based on the premise that a given activity cannot start until all those activities immediately preceeding it have been completed. This is not always the case in the field, but it is a particular limitation of this scheduling process. It is not possible to have the finish of one activity overlap the start of the succeeding activity. If overlap exists then the activities have to be further divided. The "I-J" network should also be continuous with no gaps, discontinuities, or dangling activities. The only activity without a succeeding one is the one used to terminate the project. Occasionally activities will have to be inserted which represent no work. These are logic restraints, usually called dummy activities, and are used to tie in activities that are related. Dummies are also used when two or more activities start at the same node and finish at the same node (adjacent activities). To allow each activity to have a unique "I-J" description a dummy activity is added to the end of the adjacent activities.

It is customary, but not mandatory, to have the "I" node numbered lower than the "J" node. This was originally done due to computer program limitations and, although no longer necessary for programming reasons, the practice continues because it makes it easier to locate events and activities on the network. It is common practice to number logic so that it flows from the low numbers at the beginning to the higher numbers at the end. In addition, the practiced planner numbers his diagram in bands or areas of logic, so that all of the related activities will have the same number group.

The activity description can be written above or below the arrow line. Either method is acceptable but the below the line method eliminates possible restrictions on the length of the description which may be encountered from the arrow. Durations for an activity are indicated next to the "I" node on the opposite side of the line of description.

Once the general logic has been developed and the network diagram is complete, then activity durations are added. Time is usually not considered during the development of the logic. Instead, the initial schedule is developed using unlimited time and resources. The activity durations are then added based on equipment, material, and labor limitations. The tendency is for contractors and subcontractors to make the durations

longer than they should be. This should be avoided as it may result in the network being discounted as unrealistic when reviewed at a later date.

3.4 Forward Pass

As durations are posted to the diagram, the contractor should manually add them and record the cumulative sum over the top of each node. This process is called making a forward pass. As time is added to the schedule it may be necessary to redefine certain activities, to condense others, and to expand still others. After the durations have been added to each activity the longest path through the network, called the critical path, is then calculated. This critical path determines the shortest period in which the project may be completed based on this logic and the period of time within which each activity must be finished.

The calculation of the critical path involves the determination of four separate times for each activity. The first is the "early start" (ES) which is the earliest time an activity can possibly start after the completion of all preceeding activities. Thus, the first activity has an ES of 0 or 1 (depending on whether the activities are considered to start at the end of the preceeding day or at the beginning of the day) and each succeeding activity's ES is increased by the duration of

the activity with the longest duration immediately preceeding it. The early start time is based on the assumption that each activity starts as early as it possibly can. The second time is the "early finish" (EF) which is the earliest time that an activity can be completed. This is determined simply by adding each activity's duration to its early start time. Calculation of the early activity times determines the earliest time that the last activity can be finished. These calculations are all based on the assumption that a competent job of planning has been done, activity durations have been accurately estimated, and everything goes well in the field.

3.5 Backward Pass

The next two times are calculated by working backward through the logic starting at the project's completion date. The "late finish" (LF) is the latest that an activity can finish and still allow the project to be completed within the allotted time. The completion time of the last activity, which is also its early finish, is used as the initial date for this procedure which is called a backward pass. Each activity's duration is then subtracted from its late finish to determine the late start (LS) of that activity. The late start of an activity is also the

"Milestones" are often established on a project schedule to assist project scheduling or set specific goals. Milestone dates are points in time identified as being important reference points in accomplishing the work. Milestone dates can be imposed by the owner for the accomplishment of certain activities or they can be target activities set by the contractor to let him track specific requirements. Any date can be chosen for special attention at the selector's option. He decides what dates, if any, merit closer interim attention. Milestones are usually identified on the logic diagram by a flag over the "I" node approximately the same size as that activity node.

There are many paths or logic chains through a schedule. Not all of them will be critical but there may be more than one critical path. Even those paths that are not critical because they contain float may become critical if the float is eliminated by beginning an activity later than its late start once the work has begun.

Any delay in the finish date of a critical activity, no matter what the reason, automatically extends the project completion date by the same amount. The length of the delay, its cause, the responsible party, and the willingness to accept these facts are debated quite often. On nearly every job, the usual

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move by the contractor and/or owner is to debate the issues outlined previously and refuse to modify the logic or agree to modifications. This renders the logic useless to the contractor and owner.

Thus, the identification of the critical activities is a vital aspect of project scheduling since it locates the activities that must be performed timely if the project is to be completed in the allotted time. The ramifications are that once the critical activities have been identified, the project cannot be completed any earlier without rescheduling or reducing the durations of these activities.

3.7 Float

Activities with non-matching early and late start times are flexible. That is, they do not necessarily have to begin or end on their early start or finish dates to meet the completion date of the project. This flexibility is called float and is a measure of the capability for a given activity to have its performance delayed or extended. An alternate way of looking at float is as a measure of "criticality" for an activity. The more float an activity has the less critical it is and, conversely, the less float the more critical the activity. As discussed earlier, those activities which

contain no float are considered critical and cannot be delayed.

There are two classifications for float. The "total float" for an activity represents the difference between its late and early starts. Subtracting the late finish from the early finish gives the same result. Total float for an activity is the amount of time by which an activity can be delayed without affecting the project's completion date. Total float belongs to the particular path that an activity is on. The activities along this path do not own this float. That is, they share the float such that using some of the float on one activity will reduce it by the same amount on all of the activities along that same path. This is an important concept since the ownership of float can become a point of contention during the project work and in later claims.

The other type of float is called "free float" and is calculated by subtracting an activity's early finish time from the early start time of a subsequent activity. The free float of an activity is the amount by which that particular activity can be delayed without delaying the early start of the following activity or affecting any other activity in the network. Eliminating the free float of an activity does not eliminate total float by an equal amount.

In actual practice free float does not prove to be of any significant value. Free float is only available when more than one activity immediately precedes another. In the case of the last activity in the path, free float usually equals total float. Thus, each activity in a chain may share total float but only the last activity would own free float. Contractors involved with specific activities in a chain are not concerned with free float that is not theirs, but rather are concerned only with total float of which they have a share. The value of free float is important only in subcontractor planning since it represents the amount of time he can delay his work without affecting another activity or subcontractor.

In order to use a CPM network properly, the initial data input needs to be reasonably accurate and the assumptions upon which this input is based must also be reasonable. If the input is used carelessly it will be of little importance to the contractor or owner.

3.8 Time Scaled Networks

Time scaled networks resemble bar charts and as such are more readily accepted by people since they are less imposing than arrow diagrams. However, before the time scaled diagram can be prepared, a logic diagram must be constructed. On a time scaled network the

activities are plotted in solid line to scale, with dotted connections to the event connection point. The dotted section is equal to the float in the chain of activities. The time scale should be done last, after the schedule is approved, to prevent multiple redrawings.

3.9 Periodic Updating

Schedules are not made to be perfect. The person drawing up the schedule cannot anticipate every future circumstance and eventuality. Unforeseen problems, choices, good things, bad things, better knowledge, mistakes, corrections, and surprises all have an effect on the original schedule. As the work progresses, better ideas arise on how to complete certain activities. In addition, some job managers do not plan specific work methods until the particular job is at hand. Adverse weather, delivery delays, labor disputes, change orders, and differing site conditions may also have an impact on the original plan. At times, additional activities apart from those included in the original plan may be necessary. With all of these outside influences it is apparent that a construction project will normally deviate from the original schedule.

Considerable time and effort is required during construction to check the progress of the job so that the necessary action may be taken to bring the project back on schedule or, if that is not possible, to adjust to the effects of an inevitable delay. These actions constitute the monitoring and rescheduling phases of the job schedule known as updating.

When adjusting a schedule it is important to realize that a single activity is usually so limited in scope that any loss of time on that activity is not immediately recoverable. Any corrective action, if required, is based on making up the lost time through the rescheduling of subsequent activities. In order to assess project delays and devise corrective rescheduling, an updated network of those activities yet to occur must be made. These updates often reveal shifts in the critical path and changes in the floats of activities.

In order to maintain the schedule as a realistic tool, these updates must occur with some regularity. How often field progress should be measured and reported depends upon the degree of control considered desirable. This will depend upon the size, complexity, and characteristics of the work. This progress reporting may occur anywhere from daily to monthly, or even longer. Turn around time for an update is also

important, since the schedule needs to be current if people are going to use it.

The degree of detail for the updating can also vary. Each update should attempt to identify the actual start and finish dates for each previously completed activity. If these dates are unknown, a date by when the activities had been started should be recorded. The update should also include an estimate of completion which is usually expressed as a percentage of each activity in progress. Durations of activities are adjusted according to actual field progress. Completed activity durations are reduced to zero, partially completed activities are reduced to reflect only the time necessary to complete them, and unstarted activities are adjusted to reflect any known conditions which may affect performance. Revised logic is inserted to show change orders or to reflect new or different methods of construction. Based on this new information a new completion date is then computed.

It is also helpful to have a narrative report to accompany the update. This should describe the information reflected in the numbers and dates of the revised schedule. The narrative should contain a description of progress since the last update, a discussion of problem areas, any identification of alternate critical paths, possible future problems, and

reasons for any revisions to the logic. The function of the narrative is to provide a report that is easier to read and which will serve as a tool for making it simpler to recall why certain actions were taken (4:46).

CHAPTER IV

ESTABLISHING A SCHEDULE

4.1 Schedule Completeness

No schedule will be accepted by a court to either prove or refute an alleged construction delay until it is complete. For example, a schedule that does not include procurement activities can be considered incomplete. In the case of *Dobson vs Rutgers*, a consultant was used by the owner to develop a critical path method schedule to illustrate one method of completing the contract work. This schedule was subsequently incorporated in the bid documents as an example of one feasible way of executing the project. When project completion was delayed twenty-five months, the owner was sued for failing to take affirmative action to maintain the work schedule and for disrupting the prime contractor's work schedule by directing him to perform out of sequence work (4:74).

One of the first issues to confront the court involved which CPM schedule should be used to measure each party's performance. In this case, all the parties conceded that, despite the schedule included in the bid documents, there never was a schedule approved by the owner as outlined in the general conditions, which required that the CPM consultant meet with the

prime contractor to establish a working schedule. Instead, it was found that not until the third update was sufficient data included in the schedule to consider it a complete plan for the project. The first update was complete through the building's close-in, but omitted finish activities and the second update included information on equipment installation, finishing details and some procurement items. But it was not until the third update, when the schedule reflected the General Contractor's procurement schedule, that the court found sufficient information included within the schedule to have it considered a plan for the project.

The critical path method is intended to arrange all activities required to complete a project in a logical sequence. Despite testimony that the schedule at the time of the first update reflected the manner in which the two prime contractors intended to construct the project, the court did not accept the schedule as complete until the third update due to the lack of a procurement schedule for the general contractor. Equipment procurement is a vital, although often overlooked and ignored, part of the construction schedule. Many times contractors pay little attention to equipment procurement. *Dobson vs Rutgers*

demonstrates how significant a court views the procurement schedule.

A court may accept the most complete schedule even if it was not what the contractor used to construct the building. Courts have used outside scheduling consultants' schedules prepared after project completion rather than the contractor's when the contractor did not break activities down into components which would best illustrate project delays.

A schedule indicating the manner and method of completion may also be accepted by a court even though it has not been formally approved. In the previous example of *Dobson vs Rutgers*, there was never a formally approved working plan as required by the contract. The court accepted the third update because it represented the most complete schedule and the one most frequently used throughout the job. If the court had not used the most complete schedule, since it was never formally approved, nothing would have been left upon which to measure any rights or damages. The absence of approval did not stop the court from using the construction schedule actually used to build the project as the reference schedule in the claim. Another point to remember is that by failing to complete a schedule, the party responsible has breached

its contract obligations by failing to perform according to whatever scheduling clause is present.

4.2 Substantiation

CPM schedules are not entitled to automatic acceptance. Courts require that they satisfy certain fundamental tests before they are presented to illustrate the method and manner of construction. The authenticity or validity of the data used to prepare the schedule; the intended purpose of the schedule, whether for estimating or construction; and how the schedule was actually used must be established (4:79). It is important that the contractor show where the scheduling data came from, how it was used to prepare the schedule and the purpose of the schedule. The contractor needs to explain how the schedule was developed and how it can be used to demonstrate the delay. A schedule which has no back-up documentation to show how it was developed may be rejected as unsubstantiated.

4.3 CPM Consultants

A CPM consultant may assist in the preparation or updating of a schedule. The CPM consultant's responsibility should be of a professional nature. Scheduling requires a reasonable understanding of all phases of construction. It requires the ability to

understand some mathematics, computers, data processing and drafting. It requires sufficient construction background to recognize the limitations of labor and equipment, and sufficient design background to understand how the elements of a project go together. As such, scheduling consultants should be held to "expert" standards and hired based on that fact (4:85).

4.4 Dates in the Schedule

The law does not always uniformly apply scheduling techniques to disputes in the same manner as the construction industry applies scheduling techniques to project management. Some courts see project schedules as being a definite commitment, rather than a flexible planning tool. They adopt this position despite accepting "industry" definitions of the schedule as subject to change as time changes scheduling assumptions to fact (4:85-86).

Cases holding schedules to be commitments incorrectly interpret the purpose of schedules. The misinterpretation most often occurs when a particular schedule has been presented for use on the project. In these situations, courts have sometimes incorrectly perceived something close to detrimental reliance on a particular schedule by the aggrieved party. In other words, all contractors are seen to rely on the schedule

to determine when other prime contractors' work is to be completed so that their work may proceed. In the industry, however, there is no reliance on a schedule in the same manner as the law perceives detrimental reliance. Construction schedules are a guide and management tool to plan, but are not intended to result in absolute commitments.

The General Services Board of Contract Appeals recently expressed this view that schedules are not rigid commitments. In a contract which provided a construction manager with the general authority to prepare a comprehensive construction schedule and adjust it as long as the total time allowed to perform the work was not changed, and required the multiple-prime contractors to cooperate with the construction manager in the schedule preparation and to furnish information in reevaluating and updating it, the Board recognized that changes in work sequence, CPM logic and activity durations were to be expected (4:97).

Although schedules are to be interpreted as guides, they should not be ignored. The dates in a schedule, while certainly not commitments, have to be reasonably accurate. The dates in a schedule should be flexible guides; flexible but not to be broken. The amount of flexibility has no fixed amount, but will

depend on the particular situation. The dates of a schedule will be used by the courts as guides to be considered in evaluating performance.

4.5 Contract Scheduling Clauses

As discussed above, the most frequent and significant error made in the interpretation of scheduling clauses occurs when the dates in a schedule are interpreted as commitments rather than guides. Schedules are developed according to industry standards to establish the sequential order of the work activities; to provide direction and control of the work; to anticipate the need for material, equipment and labor; and to facilitate project coordination. Schedules are not developed to identify completion dates for each activity. The only committed dates in a construction schedule are the project completion and intermittent milestone dates established by the general conditions or by the contractor. Schedules are planning tools, not contract commitments (4:158). Standard contract scheduling clauses should be changed to clearly identify the industry's use of schedules as guides. Courts and boards have also identified scheduling clauses' failure to assign ownership of float. Standard scheduling clauses that imply definiteness in the sequence, start, duration or finish

of portions of the work should be eliminated and suitable words describing the flexibility inherent in those elements of the scheduling process substituted.

4.6 Benefit of Float

A key issue in project scheduling is the question of whether the contractor or owner should receive the benefit of float time. Some construction contracts expressly state who has the control or benefit of float. Some state that no extension of time will be granted unless the delay directly affects the critical path, thus requiring the delay to absorb any float present, transforming a non-critical activity to a critical one, before a time extension will be granted. Many construction contracts, however, make no reference to this issue.

Ownership of float affects the method and manner of calculation of delay. If the contractor owns float, the beginning of a delay should start at the early finish date of any activity whether critical or not. This maintains the contractor's control over the differences between the early finish and late finish times of all activities. If the owner has the benefit of float, delay calculations should begin at late finish dates of critical activities only. The difference is that if the contractor owns float,

noncritical activities which are delayed should receive time extensions, but if the owner does, only delayed critical activities receive extensions of time.

Late finish times are less meaningful than early finish times. This is true because of the difference between the forward and backward pass. The forward pass more accurately reflects the contractor's thinking since it begins at the project's start date and continues through the planned construction sequence. In contrast, the backward pass starts at the end of the project and works backward, through the construction sequence. The late finish dates are thus less meaningful to the contractor because of their artificial nature (4:106).

Courts and boards that have considered the ownership of float have not reached similar conclusions. Contributing to the inconsistent decisions is the conflict between two common provisions in construction contracts. The provision that the risk of construction lies with the contractor tends to support owner claims of float. This generally states that the unknowns of construction which cause risk are the contractor's responsibility. Delays which reduce float are the contractor's risk.

The second provision which states that the contractor is resposible for the means, methods and

techniques of construction tends to support the contractor's claim to float ownership. If he is responsible for the means and techniques of construction, he should also be able to alter them as he pleases. He should be able to reduce or extend the time required to accomplish any activity which may result from a change in method or technique.

Owners and designers are frequently advised to grant all the contractor's requests for extensions of time as a technique to reduce, if not eliminate, the contractor's delay claims. Granting extensions of time as they are requested by a contractor will deny the contractor the opportunity to connect a denied time extension to a cost overrun or else make a legitimate delay claim longer. Granting time extension requests maintains the contractor's "cushions" of extra time. It maintains the contractor's ability to measure and plan with an updated and current schedule since it gives the contractor full use of his original float. Thus, there is industry support for the contractor's ownership of float.

Using early start and finish dates to measure the liability for some part of extended performance time, but not all, fits well the more meaningful nature of early start dates. The contractor's early start and finish dates are the real dates of the schedule.

However, determining at what point one's use of float begins to cause the other damage is not easy. When the line is crossed an adjustment is due. In some cases the weight of float ownership is determined by the contribution to the delay. In other cases the one who last uses the float, and consumes activity float causing a delay to the project completion date is held responsible for the delay. In any event, the decision maker should recognize that his responsibility is to the project rather than to any individual or party.

4.7 Mistakes in the Schedule

The critical path method of scheduling requires the logical analysis of all the individual tasks that enter into the complete job. To be logical, a CPM scheduler must accurately reflect both the contractor's intent to construct the job and the practical field restraints that apply to the job activities. Failing this, the CPM schedule is not an adequate tool. It may fail for any number of reasons:

1. Impractical construction techniques.
2. Mathematical errors.
3. Intentional deviation from the manner in which the contractor intends to complete the job.
4. Failure to properly evaluate and consider scheduling restraints.
5. Failure to consider practical constraints.

6. Mistakes in updating the original logic to show delays.

Errors in the schedule which do not concern logic or durations may require rejection. Schedules may also be attacked for errors in activity durations or detail.

To be useful, a schedule must accurately reflect both the contractor's intent to construct the project and the practical field restraints that apply to the activities. The schedule must be a logical analysis of the individual activities that make up the project. This applies to schedules used to manage the project and those subsequently constructed to prove delays. Failure to do so may greatly reduce the effectiveness of the schedule in proving a delay claim.

A pre-bid schedule available with other bid documents should be treated as only one method to coordinate the work. The contractor should be able to choose other methods as the contractor controls the means, mehods and manner of construction. A pre-bid schedule should be considered an identification of time for purposes of wage rates, material prices, or interest rates. The critical path method acknowledges that there are many ways to construct a building. Schedulers may escape responsibility for errors in the pre-bid schedule by requiring the contractor to furnish a schedule once the contract has been awarded.

Contracts which contain an independent scheduling requirement will shift the scheduling responsibility to the contractor, despite the presence of a pre-bid schedule.

4.8 Mutual Responsibilities

The majority of scheduling clauses in construction contracts attempt to make the contractor solely responsible for the planning and scheduling of the work. However, the owner or designer assumes certain responsibilities by retaining the authority to approve or disapprove the schedule. The owner or designer agrees that he will fulfill his own performance requirements in a timely manner according to the approved project schedule. These requirements may include shop drawings, delivery of owner furnished equipment, etc. In addition, failure of the owner to approve a submitted schedule may not release him from these responsibilities to perform in the time shown on the schedule.

General contractors may be required to perform within schedules they have imposed on subcontractors (4:124). In other words, if a sub is required to follow a schedule drawn up by the prime contractor, then the prime contractor has a responsibility to make work available to the sub as shown on the schedule.

Courts have stated that in these situations performance by the contractor of his part of the bargain is a constructive condition precedent to the duty of the subcontractor to perform his part of the bargain. The contractor is required to meet the schedule he imposes on his subcontractors before he can demand performance by the subcontractors. Suppliers may also be held to their responsibilities under a schedule.

4.9 Requirements for Updating the Schedule

Failure to incorporate changes in the work and time extensions prevents a CPM schedule from reflecting the current status of work performed. An inaccurate schedule cannot be used to control the progress of the ongoing work, it cannot show the effects of delay on the project's completion, and it cannot represent the actual manner in which the project was constructed. A schedule which has not been correctly or completely updated will not generally be considered a satisfactory representation of the construction sequence or duration.

The CPM schedule identifies many paths through the schedule. Not all are critical, but those that are not critical because they contain float may become critical if the float is eliminated. In the same manner, those paths that were originally critical may develop float

if a new longer critical path develops. Thus, as the schedule is updated the critical paths are likely to change. Since the court will use the best available evidence, it is likely that the most recent and updated schedule will be used (4:130). A contractor who bases his claims on the original schedule without regard to updates may be in for a rude awakening.

4.10 Changes in Scheduled Sequences

Perhaps the most important part of any schedule is the order of its activities. The activity sequence is relied upon to order material and to arrange for equipment and labor much more often than are the dates in the schedule. The anticipated sequence represents the contractor's bid intent. It defines the amount, and thus cost, of material and equipment estimated to complete the work and more importantly, when the material and equipment is due. Changing the sequence of a schedule may change the entire management plan forcing succeeding work to begin without all necessary material or equipment onsite. It may impose an unanticipated inefficiency on the contractor by requiring him to furnish additional material or labor to compensate for this change, thereby increasing the contractor's costs. Unlike the dates in a schedule, which should be considered sufficiently flexible to

permit variation, sequencing will invite reliance by parties using the schedule.

There are certain implicit duties between the parties of a contract, particularly the duty of each party not to prevent performance by the other party. Although with construction contracts these duties are interpreted with the uncertainties, vagaries and necessity for change inherent in construction projects, there can come a point when the necessary latitude of discretionary action has been exceeded. Out of sequence work can indicate situations where the implicit duty not to prevent performance of another contracting party has been breached. Not all sequence changes will cost more time and money. Judgement is required to determine those sequence changes which do and do not result in additional costs. The parties of the contract should exhaust all other alternatives before leaving the job due to sequencing problems (4:131-152).

4.11 Schedule as Notice

The schedule also has a potential use as a notice of changed conditions and delay. Courts have not always accepted the schedule as implied notice of performance deviations, but that possibility does exist. Those schedules updated frequently and

submitted to the owner may serve as notice of alleged delay. For updated schedules to constitute notice of delay, the update must be shown to reasonably call attention to the delay (4:157).

CHAPTER V

DOCUMENTING A CLAIM

5.1 Proving an Impact

The idea that a poor quality schedule is useless in running a construction project also applies when trying to establish a construction claim. However, it has not always been easy to prove to a lawyer or judge that poor logic will make an entire stack of computer printout worthless even though it looks impressive. There is still the mystique of the computer and the idea that if the computer says it happened, then it must be true. It is necessary to realize that many disputes have been won using totally useless CPM work as a key reference in the claim. Thus, it is desirable to understand some of the techniques and drawbacks for when a contractor is attempting to demonstrate a delay and also for when a claim is invalid so that the claim can be refuted.

There are many ways to prove and win a case using CPM schedules which employ very limited arrow diagrams, since it is relatively easy to show the effect of a change on a small network diagram. However, it becomes more difficult when one attempts to show the effect of a change on a detailed 1000 activity network. Many techniques for evaluating the impact of changes on a

schedule are still in the formative stage, which usually means that the use of an experienced CPM construction oriented person is advisable, if not required. No matter what the contractor thinks he can do with a CPM network, the impact of a change is best shown by a person who is well versed in scheduling mechanics and who is able to show what went wrong with the construction process to cause the impact and why it happened.

There is no one method that is consistently used to prove delays or entitlements to time extensions. Each particular situation requires a certain amount of judgement from the person working with the schedule. However, whatever method is used, an ordered procedure should be employed to discipline the evaluator's analysis. This provides a framework from which judgement can be applied in controllable and understandable increments.

The first thing that needs to be established is the job status at the time the work was delayed or the performance was extended. Secondly, the delays should be placed into the schedule of concern in the chronological order in which they occurred. Thirdly, it should be determined what affect each delay had upon that particular network schedule to determine what this meant to the contractor's performance.

5.2 Defining Job Status

Defining the job status can be a difficult problem. In the event the analysis and delay are less than thirty days apart, it may be done by a thorough job walk-through where the progress in each area is recorded. This can be followed by an examination of the current material schedules, a determination of the actual amount of materials available at the site or stored off-site, a review of present equipment availability and capacity, and a review of labor availability. A review of the project's progress history should also be made since a later examination of the contractor's previous progess rates may give an indication of what could have been reasonably expected in the future. By combining all of this data, the evaluator can more clearly define the project's current status.

In the case where the analysis occurs at a time greater than thirty days, a situation more likely to occur, the condition of the job site at the time of the delay can probably no longer be accurately described by a visual examination. The evaluator must instead rely on the historical records of the project. The variety and quality of job records, including daily reports, quality control reports, etc., will differ depending on the contractor and/or contract requirements.

The initial step in reviewing the project records is that of determining what records are actually available. The answer to this question will assist the reviewer in determining the time and travel that will be necessary to study the records, how many people will be required to complete the review, and whether all normally maintained records are available. It will also help him in getting organized so that he does not miss any areas of potential information.

The next step is to check the project's updated progress schedule which was updated closest to the actual occurrence of the delay. Actual start and finish dates may have been recorded on the updated schedule. If they have not been recorded, then it may be possible that completed activities were noted along with an evaluation of each uncompleted activity's status. If actual dates have been recorded, the evaluator can compare them with other records to insure their accuracy. If partially completed or completed activities have been indicated, there is still a general frame of reference to which the specific dates can later be added, if available. In either case, the person reviewing the records will have his task made easier. A sufficiently detailed schedule with actual completion dates is enough to define job status.

If there is no schedule available or the schedule provided is not of good quality to measure the job status, then the evaluator may have to go to the records from job progress meetings. These should normally provide information on how the job was actually built. These meetings usually indicate how particular portions of the job were going and if any problems or changes to what was originally planned had occurred. Items normally found are subcontractors' locations, interference among various subcontractor crews, missing material or equipment that was needed to complete activities, and various problems due to design conflicts or ommissions. This information can help the evaluator identify the progress of the job. It should be noted that progress meeting notes may be available from more than one group (i.e. owner, subcontractors, suppliers, etc.).

Another report that may assist the evaluator is that generated from the contractor's job cost control system. Generally, progress will have some relation to the amount of and change in costs recorded on the cost report. As costs increase, progress is made and can be measured to define delay. The smaller the interval between reports the closer the chance that one cost report will be near the date the delay or change occurred. The cost report is intended to capture a

picture of the project in numbers at a particular point in time. As such it may be relied upon to provide a more reliable source of information than the minutes of progress meetings. A disadvantage of the cost control report, however, is the problem with relating cost codes to the activities on the schedule. For example, the cost code for concrete may be difficult to tie to the construction activity for the floor slab. In addition, some cost reports will have greater detail than others. In any case, the cost report may provide some basis for determining the project status.

Job status at the time of a delay can also be defined through the use of progress photos. When available these can be used to show, pictorially, the project's progress at a particular point in time. Problems with progress photos can include the lack of sufficient detail and their relative infrequency which may hinder the person trying to provide an accurate measure of the progress at any one point in time. However, they can be combined with the progress meeting minutes and job cost reports to provide for sufficient backup for defining job status.

Other areas where the evaluator can look for an indication of the job status are the correspondence files and through interviews with persons actually involved in the project. The correspondence files are

generally not as reliable since it is not very likely that job progress will be discussed to any large extent. The interviewer may end up spending large amounts of time reading the exchange of letters or memos without finding that much useful information. The amount of information that can be obtained from interviews will depend on the particular person being interviewed and his memory. In some cases, if either party has considered or initiated litigation, formal statements or depositions may be available (4:189).

5.3 Inserting Delays Into the Schedule

Once the status of the job at the time the delay has been determined, it must then be transferred to the job schedule itself. If no job schedule exists, then one must be created. The effect of the delay on the progress of the job will be measured by the schedule. The analysis of the delay depends on it.

If an existing schedule is used to record the job status and measure delay, then the remaining logic must be carefully reviewed to determine whether the project was built according to it. Durations should be checked and, if the sequence and order of construction has deviated from the intent of the original schedule, appropriate revisions should be made. An accurate schedule is important not only to support the schedule

itself, but also to protect it from attacks which argue that the schedule cannot measure the effect of the delay since it does not accurately show how the project was built. In the case of a schedule being created because an insufficient one existed, the logic should reflect the actual manner of construction or, if the contract is not yet complete, the contractor's intent.

When inserting the delays into the schedule the evaluator needs to place them in the order in which they occurred. The delay must be placed at the correct place in the logic. This requires a certain amount of judgement on the part of the evaluator. Once this is done the remaining logic must be studied in order to revise it to reflect the delay and its impact. Some of the questions that must be answered during this study are:

1. Were activity durations increased or decreased?

2. Were labor requirements increased?

3. Were more craftsmen required to work in the same area, thus affecting productivity?

Answers to these questions will provide an insight into how the remaining work schedule has been affected. As the effects are identified, logic and durations must be subsequently revised to indicate the new way in which the construction had to be completed. It can be seen that the evaluator must understand not only the

fundementals of putting a schedule together but also how the construction process functions so that the delays can be accurately inserted.

When inserting more than one delay into the construction schedule it is important to determine the effect of previous delays prior to inserting later ones. Each delay should be measured separately since different parties may be responsible for the different delays. This will allow for a proper division of responsibility during the final assessment. In addition, a particular delay's effect on the schedule may be greater than the mathematical value of its duration. The most obvious example of this is a short delay which forces an unanticipated winter shutdown. Such an instance results in a much larger impact than the actual delay itself. Each delay must be evaluated separately simply because CPM is a dynamic method. The schedule changes as assumptions become facts. A subsequent delay will alter the impact that earlier delays had on the schedule.

5.4 Analyzing the Schedule

The final step requires that the schedule, once revised to show the effects of the delay(s), be analyzed. The delay(s) must be examined to determine what they have done to alter the project performance of

the contractor. This can be done by performing new forward and backward passes to calculate the remaining activities' new float, to define a new critical path, and, very significantly, to define the revised project completion date. Once this has been done the evaluator should prepare a narrative description of the revised schedule. This narrative should describe the manner in which the project was or will be completed as shown by the revised schedule's new logic and durations (4:191).

To summarize:

1. Each delay should be inserted and analyzed separately,

2. Each succeeding delay should not be inserted and analyzed until all preceeding delays have been completely analyzed, and

3. Each delay should have its own narrative description of effect and value.

5.5 Network Analysis

Now that a general method for looking at an impact's effect on a network schedule has been established it is important to realize that several variations of the project schedule can be used to demonstrate the effect of an impact. Network analysis for claims presentations has traditionally revolved around the use of three general network schedules. These are:

1. A reasonable as-planned schedule,

2. An as-built schedule reflecting all delays, and

3. An as-adjusted schedule reflecting only the delays of concern (9:28-29).

These network schedules are used together to illustrate the final impact of the changes on the contractor's original schedule.

The as-planned schedule represents the starting point or "reference" schedule. The purpose of this diagram and analysis is to establish the time in which the project would have been completed minus any delays. This is usually the contractor's initially submitted project schedule which was, hopefully, approved by the owner. Items that need to be shown are whether or not the schedule was issued to the owner, if the schedule was accepted or rejected by the owner and on what basis, and whether or not a revised schedule was subsequently submitted. Answers to these questions will help to establish the reliability and usefulness of the "reference" schedule. The as-planned schedule should take into account any time saving methods that may have been discovered during the work. Adjustments should also be made to reflect errors in logic or duration of activities. Where the as-planned schedule deviates from the original CPM network, the contractor should note the changes made and the reasons for them.

In the case where the schedule was not issued to the owner but was still used by the contractor to

manage his job, then the schedule should be verified by another party as to its feasibility. If the contractor used a bar chart schedule it should be converted to a network diagram. It must be shown that either the schedule was the only one possible or at least was a reasonable method for completing the project on time. In addition to verifying that the schedule is reasonable, it is important to demonstrate that the schedule is mathematically correct and logical. This can be done manually or through the use of a computer.

Once the as-planned schedule has been established, it is necessary to prepare a schedule based on how the work was actually performed. This is what is known as the as-built schedule. The as-built schedule can be formed based on the basic job records, which were detailed earlier in this chapter. The actual times for activity starts and finishes, gaps in the work, changes, delays, weather problems, strikes and other impacts on the work are shown on this schedule. The purpose of this diagram is to show all of the delays that affected the project, to identify the activities that were affected by those delays, and to display the effect of the delays on the project completion date. If desired, these delays can be highlighted by a color coding on the as-built chart for more impact.

The analysis which accompanies the as-built diagram should indicate the points where it conforms with the as-planned schedule as well as where it differs. Differences in the critical path should also be noted. The analysis should address the duration of activities during construction and any changes in the sequence of activities from the as-planned diagram. An explanation should then be offered for the effect any changes in the activity durations or sequences had upon the eventual completion date of the project. This is important since certain changes to durations or activity sequences during the construction operation can affect performance from that originally anticipated. One day of delay on the critical path may not always result in a day of delay on the project. A delay may be mitigated by excess manloading, overtime, or shifts in sequence which apply pressure to the critical path.

In addition to a graphic, time scaled as-built schedule, other charts can be prepared for comparison to the as-planned schedule. These include manpower graphs, actual costs, charts which show the shifting of crews abnormally from the planned work sequence, etc.. However, the as-built diagram is an especially valuable part of the CPM claim presentation with its overall

ability to graphically segregate and identify delays and the effect of those delays on the project (9:5-20).

The final diagram typically used in a claims presentation is the as-adjusted schedule. The as-adjusted schedule can be constructed in one of at least two different ways. It can take the reference as-planned schedule and insert into it any owner caused delays in order to determine a theoretical time entitlement due to the contractor. In other words, here is how the contractor planned to complete the work, here is how the owner impacted that plan, and here is the effect of that impact on the contractor's plan. When all of the delays are inserted into the as-planned schedule it should give a fairly close approximation of the as-built schedule. If not, the schedule should be studied to see if any delays were incorrectly applied or if there were other causitive factors. Once this is done all of the delays that are not of concern are removed. This schedule when compared to the as-built schedule should determine the amount of time that was due the contractor (7:372-376).

Alternately, the as-adjusted schedule can be constructed by taking the as-built diagram and removing all of the delays which affected the critical path and that were excusable. The resulting "adjusted" schedule should demonstrate the effect of the delays in

question. The as-adjusted schedule is then compared to the contractor's actual performance (as-built). The comparison shows whether or not the contractor was ahead or behind his schedule or how the contractor may have mitigated damages during the delay. In most cases, a pretty good correlation between the contractor's actual performance and the effect of owner caused delays can be established. The amount of delay is determined by the difference in time between the actual completion date shown on the as-built CPM and the completion date shown on the as-adjusted CPM.

In some cases, the method of removing delays from the as-built diagram may prove to be unsatisfactory since the delays in question may have so altered the sequence of construction that a realistic adjusted diagram cannot be prepared by just removing those delays of concern. It may be that if the delays were removed from the as-built diagram and the actual durations were adjusted back to the proper durations without the delays in question, the result could contain an inherent contradiction since the adjusted durations might be impossible considering the altered sequence. In other words, each delay may have required such drastic changes in sequence that it would be impossible to provide a realistic as-adjusted CPM without adjusting the actual sequence. Thus, it may be

necessary to prepare the as-adjusted CPM by adjusting both activity durations and sequences to arrive at what would have been a realistic schedule without the delays in question.

All three of these schedules are used to graphically display and establish specific durations of delays, to sort out concurrent delays, to show disruption caused by extra work, to prove acceleration, and to demonstrate loss of productivity claims. Each presentation may vary, but the use of these basic diagrams will be important.(11:28-30)

No matter which approach is taken, the contractor must be careful to adjust activity durations which may appear to be contractor delays, but are really the result of the extended duration caused by the owner. For example, in a severely delayed contract a contractor may delay transmitting samples or submittals to avoid problems with changes in products or damage to material which may be delivered long before the installation could be made.

5.6 Delay Claims

Delay claims have been responsible for the majority of usage of CPM schedules in claims' analysis. A delay claim involves the proof at entitlement for extended duration type expenses. In other words, those

expenses which arise solely because of the extended time on the project that the contractor has encountered due to delays beyond his control. Examples of these expenses are extended field expenses, wage escalation, extended home office expenses, extended equipment expenses, etc.. The extended duration of a project can result from a number of causes, some of which may be the responsibility of the owner (suspension of work or changes), some of which may be the responsibility of the contractor (submittal delays or labor inefficiency), and some that are neither party's responsibility (strikes or acts of God).

The value of a CPM analysis when used on a delay claim is its ability to visually show and segregate those delays which are the direct responsibility of the owner, the contractor and neither party. This allows the effect of each party's delay on the project completion to be shown so that monetary amounts can be calculated. The method of determining owner initiated delays is to first determine the date upon which the contractor would have completed the work minus the owner's interference. The next step is to determine the actual date of completion of the work. The difference in these two dates is the extended period for which the contractor had to remain on the job. It must then be determined whether the aggregate amount of

owner caused delays is equal to or more than the extended period of performance. If the extended period of performance is less than the amount of delay caused by the owner then the contractor is only entitled to the extra costs associated with this extended period.

Based on the above it is apparent that the CPM analysis must show two things if it is to be used to prove a delay. First, it must show when the contractor would have finished his work without the owner caused delays. Second, it must show when the contractor would have finished his work minus either the contractor's or noncompensable delays. This measure would then give an accurate account of the owner caused delays.

5.7 Acceleration Claims

Acceleration is another type of claim for which a CPM schedule can be used. A claim for acceleration arises when the owner forces the contractor to speed up his work. This can come about in several ways. The owner can give the contractor direct instructions to increase his efforts or he can "constructively" force a contractor to accelerate his work. The usual way to constructively force a contractor to speed up his work is by not recognizing his request for a time extension due to an excusable delay. This forces the contractor to work at a higher rate in order to finish the job

according to the original schedule. If it is later determined that the contractor was behind schedule for a justifiable reason then the owner has tacitly forced him to accelerate his work even though no formal acceleration order was given. Normally a contractor who accelerates is forced to apply excess manloading or overtime.

Claims for acceleration have been long recognized by the courts and boards. However, proving that a claim exists and, if justified, determining how much the contractor deserves has been a difficult problem. A contractor who is accelerated is entitled to recover increased costs so long as it can be proven that the project was on or ahead of a properly adjusted progress schedule at the time the contractor was forced to accelerate. Even if the contractor was not on schedule he may be entitled to a portion of the costs incurred if it can be shown that the owner failed to withdraw a formal acceleration directive once the contractor returned the project to the proper schedule. The case may also arise where the contractor was on schedule at the time of the acceleration and subsequently fell behind schedule because of his own delays. The contractor would, in theory, be limited to recovery of the acceleration costs for that period when he was still ahead of the properly adjusted schedule. In any

case, the contractor will usually only be entitled to those costs he incurred while on, or ahead, of a proper schedule.

The proof of an acceleration claim is very similar to that used for a delay claim since both require a demonstration of delays and time extensions. The difference is that in a delay claim the contractor must identify those delays for which the owner is responsible while in an acceleration claim he must identify those delays which would have justified a time extension. This may include acts for which the owner is responsible, strikes, acts of God, and other items considered excusable but that are not compensable under the terms of the contract. An acceleration claim also differs in that a proper analysis normally requires that the court or board focus its attention upon the specific period of time during the work when the acceleration was initiated. This is so that the board or court's attention is directed to the status of the work and work activities at the time of the acceleration directive.

The only difference in presenting an acceleration claim is that the as-adjusted diagram will show those delays which are the fault of neither party as well as those caused just by the owner. In addition, the development of the as-adjusted diagram should highlight

the status of the project at the time of the acceleration order since the job status at the time of the acceleration order will be a major point of contention. It should be noted that the contractor may be entitled to a time extension even when a contractor delay is concurrent with the excusable delay. This may occur when it can be shown that the excusable delay would have happened, delaying the project, no matter what the contractor did. It may also be helpful to present a written discussion on the status of the project at the time of the acceleration order.

The basic purpose for the as-adjusted CPM network in an acceleration claim is also different than that used for a delay claim. In the delay claim the adjusted CPM is utilized to show when the project would have been completed minus the owner's delays. In the acceleration case the purpose is to show that the contractor was making adequate progress when the acceleration order was given and was thus entitled to finish at a later date than the actual completion date shown.

The as-adjusted diagram is prepared by taking the actual durations which were recorded on the as-built diagram and then inserting the justified time extensions. It is important that the contractor take into account any loss of productivity or disruption

which may have been encountered because he was unable to utilize a more economical scheduling of men, equipment, and material. Only if such disruptions or productivity losses are considered can the total amount of excusable delay affecting the critical path be determined. By basing the time extensions due the contractor upon a reasonable balance and spacing between activities and upon a reasonable allocation of resources, men, equipment, and material, the contractor should receive time extensions which cover the delay actually incurred. This will account for the actual delays encountered as well as any disruption type delays to subsequent operations in the project sequence. This requires a careful exercise of good judgement and may be very complicated.

5.8 Other Uses

Other situations where the employment of a CPM network may prove to be advantageous are those claims that involve the performance of extra work or the loss of productivity. In these instances the contractor wants to be able to prove the increased costs of labor, material, and equipment due to actions of the owner. In most cases it will be much more persuasive to use methods other than a CPM network.

One method is a day by day cost analysis of all the extra work and productivity loss expenses. This type of analysis should be prepared at the same time as the actual disruption and/or extra work. The increased costs should be charged to a separate cost code to separate it from the everyday costs. While it is usually difficult to obtain all of the costs resulting from a major change or disruption, this technique is considered the best since it is an accurate accounting of actual costs recorded at the actual time they occurred.

Another method is the use of efficiency comparisons. The contractor makes a comparison of the normal versus disrupted periods. This can be done when the contractor's monthly labor reports, which are based on actual work data, reveal that during periods when the contractor was not being disrupted he installed a fixed amount of work for a fairly stable cost. The later records can then be used to demonstrate that during the period of productivity loss or extra work the contractor was installing the same fixed amount of work for a higher cost. This comparison of normal versus disrupted periods can be used to prove what the increased costs were.

In many cases, however, there are no day to day records which can accurately show the extra work or

productivity loss costs. It may have been impossible to maintain records which could reflect the full impact of the problem. It may also have been difficult to determine what a normal period was for comparison to the disrupted period. In these cases the use of a CPM network may be useful in support of an engineering estimate. The network can be used to graphically demonstrate the nature and extent of the difficulties encountered and to provide an alternative baseline against which to measure the increased costs. Even in the situation where one of the two previous methods had been used it may be desirable to use a CPM network to provide the court or board with an alternative proof against which the costs can be backchecked.

The use of CPM techniques in productivity loss and extra work claims is not yet widely recognized. The contractor may want to take the as-planned schedule and overlay it with the as-built schedule to show the extent of the major disruptions. He may also want to show certain activities which highlight how the contractor was forced to jump between various activities or how he had to switch his planned usage of various trades. Another method is to take a time span diagram and attach a matrix to show the difference between each activity's planned duration and what actually occurred. This can help in showing the extra

time the contractor had to spend on activities due to owner forced disruptions. Even when the contract completion date was not extended this can be useful by showing that certain activities required more resources and effort than that originally planned.

Whatever method is used, it is most important that a competent analysis be attached to show the nature of the major disruptions, why they necessitated the revised sequences of installation and how these resulted in extra costs. It should demonstrate any added steps that were required and that could not have been reasonably foreseen in the planning process. This analysis is most important because without it even the most impressive network may be worthless to those who do not understand the CPM technique (9:20-39).

CHAPTER VI

PRACTICAL CONSIDERATIONS

6.1 Network Schedules and Navy Construction Contracts

Navy Construction Contracts contain several general clauses which address the use of progress schedules and several which address the evaluation of changes or excusable delays. The Federal Aquisition Regulations (FAR) prescribe the exact wording for these clauses which are found in the General Provisions (GP). A few of the more important provisions which may require some knowledge of network evaluation techniques are presented below.

As mentioned in Chapter Two, prior to 1968 the Rice Doctrine made delay costs uncollectable in the Federal sector. However, in 1968, several changes were made to the FAR which caused like revisions to the GP clauses. Two of these were the "Changes" and "Differing Site Conditions" clauses. Before the 1968 revisions to these clauses, estimating the cost/time for a modification or impact was straightforward, with only the direct changed work to consider. The revised clauses added a new dimension to the estimate; it now had to address all of the remaining work, including any effect that the impact may have had on the unchanged work.

The Naval Facilities Engineering Command prefers that the terms of all contract modifications be settled before the contractor is allowed to proceed. This requires that there be timely action by both the Navy and the contractor in order to achieve an agreement on a fair and reasonable price, including any additional time, for accomplishing the affected work.

Many times it is difficult to reach a timely settlement on modification costs. The reasons include: the lack of contractor incentive to agree before the work is accomplished, the increasing number of modifications being processed, and the lack of guidance or experience by government representatives in developing reasonably reliable estimates of cost/time impact on the unchanged work.

Since impact evaluation techniques are still in the formative stage the preparation of the government estimate can be quite difficult. This may result in delays in developing the government estimate, which in turn can result in delays in negotiations and ultimately can result in higher costs for the changed work or possibly even a later claim for impact. Negotiations can be difficult since the Navy and the contractor may have different ideas on how to evaluate the impact of a change or delay.

The GP clause entitled "Progress Charts and Requirements for Overtime work" establishes the basis for requiring the contractor to submit his progress schedule for approval. Each contracts' Special Provisions (SP) will include a clause, supplementing the GP, to indicate the type of schedule required. This will either be a network analysis system (usually employing CPM techniques) or a bar chart.

When the government approves the contractor's progress schedule it has accepted the schedule as a practicable way of accomplishing the work within the contract completion time. As long as actual progress meets or exceeds that schedule, the originally approved schedule remains valid. The purpose for requiring the contractor to submit a progress chart is primarily to assure the government that the contractor has a reasonable plan for accomplishing the work within the specified time. The progress chart provides both the government and the contractor a common basis for evaluating the acceptability of the actual progress as the work proceeds. The progress schedule often must be revised for reasons other than contract modifications. The government should take prompt action when critical activities are delayed to the extent that the current schedule no longer represents a viable plan for

accomplishing the remaining work within the specified time.

The GP clause "Progress Charts and Requirements for Overtime Work" gives the government the right to order the contractor to take actions to improve his progress and to require the contractor to submit for approval a revised progress schedule showing how he plans to regain the lost time and complete the project on schedule. The contractor must bear the cost of complying with the government directives pursuant to this clause. Thus, the government is justified in using this clause only when the delaying factors are attributable solely to the contractor. If the progress schedule, used to determine that the contractor is behind schedule, is not up to date, including allowance for all time extensions, the contractor may have grounds for claiming reimbursement of costs incurred due to government directions even if the delay is primarily caused by the contractor. Thus, if the government has issued a notice to proceed (NTP) on a modification prior to settlement of the terms of the modification with regard to time, there can be no up-to-date realistic progress schedule and the pertinent contract provisions cannot be enforced.

It is advantageous to settle all NTP's as soon as possible so that the contractor has more incentive to

accomplish the work in the most efficient manner, the risk stays with the contractor and the burden of proving that the price is reasonable remains with the contractor. The use of NTP's with a price not to exceed a determined amount can be used but they require the government representatives be reasonably confident of their estimate. A disadvantage of this approach is that the issue of time extensions, including any extended overhead, will probably not be resolved. A major benefit of settling modifications prior to performance is that it allows for prompt revision of the progress schedule, thus maintaining an accurate knowledge of the sequencing of the remaining work, the final contract price, and the final completion date. The schedule then remains a realistic tool for determining the impact of changes and other impacts on the contractor's operations. An up-to-date CPM schedule is needed to reasonably forecast the presence and extent of any future impact(s).

6.2 Difficulties in Network Evaluation

Evaluating the effect of scheduling changes and delays is difficult because all of the required information is not always available. In real life the records are not always as complete as they should be. Contractor records are incomplete, lost, or destroyed,

peoples' memories fail, and cost reports are inadequate and/or ignored. No attention is payed to the original project schedule; work is completed when and as available. Whenever needed information is missing or inadequate the evaluator must either approximate the required facts from available sources or else substitute his judgement. The more approximation and judgement required, the less accurate the schedule analysis becomes.

The greatest obstacle the evaluator must overcome is the extreme difficulty in recreating a truly accurate historic job status. As-built schedules are not always totally reflective of the job progress because of the conflict between the "I-J" principles of scheduling, which state that preceeding activities must be complete before succeeding activities can begin, and the actual overlap of construction activities in the field. In the usual circumstance, one activity will not be totally completed before another is begun. Most activities are not totally independent; they are constantly complementing each other. Many activities of work may be left at the 95 percent level of completion. When are those activities considered to be complete? Some items are started and then abandoned in favor of other more important work. Are these activities considered to be started? If an activity

takes five actual days to complete but the work is spread over a three week period what is considered to be the actual duration of the activity? There are no clear cut examples in the real world of construction. Everything is relative to the person looking at the particular schedule or activity and the judgement he uses. Because of this, the demonstration of the effect which a delay has had on a project can prove to be extremely difficult.

Other problems include the confusing output that is generated from the schedule. A logic diagram, computer printout, and duration schedules can be confusing to someone who is not familiar with construction schedules. This is especially true for the owner or attorney who knows little about the construction process. Thus, it may be advisable to convert the revised critical path schedule to a bar chart or time scaled network which may be much easier for most people to understand. The bar chart can demonstrate extended performance easily when a line representing the originally anticipated performance is compared to a line representing the actual performance, both displayed on a time scale. The bar chart merely illustrates the CPM study since the actual schedule analysis is done using the critical path method. The bar chart is useful only to show, in a simple way, a

complicated, interrelated activity delay which might be confusing on a CPM diagram.

Contractors or owners can either emphasize or reduce the effect of any delay or time extension even before it occurs by following certain scheduling techniques. A contractor may decide to reduce the amount of float he puts into his schedule. The reasoning behind this is the less float available for an activity, the less time before a delay will cause it to become critical. Conversely, owners will want to show more float since this allows for more flexibility for changes that require additional time.

In a case involving the firm of C. H. Leavell and Company, the government alleged that the contractor's schedule contained excessive durations to reduce the amount of float present (4:193). The government reasoned that the excessive durations were one reason the schedule could not be properly analyzed. The contractor argued that since the specifications did not define the amount of time each activity could take, he was free to define the schedule as he saw fit.

In this case, the contractor allocated 285 days for "mechanical-electrical rough-in". The government's contention was that 120 days was a more reasonable duration for that activity. The duration was important because enough float was present for a duration of 120

days but a delay to project completion occurred if it was 285 days. The Board of Contract Appeals found that the analysis of the schedule was made difficult by the lack of breakdown of this activity. The Board concluded the duration, and thus the length of the delay, lay somewhere between the two times and rendered a "jury verdict" decision. This points out the fact that the best schedule is an accurrate schedule.

Another technique often used to emphasize or reduce the impact of delay is to adjust the status of a job at the time a delay or change occurred. Most authorities agree that a delay must be measured at the time it occurred during the construction process. However, as earlier pointed out, it is difficult to define the past status of a job, especially if poor job records were kept. Arriving at the project status at any particular point in time requires a considerable amount of judgement. This final judgement will influence the amount of delay. In the case where there is shared delay the definition of where the delay occurred may be important in determining the correct allocation of responsibility.

The best way to show the effect of a delay is to sequence the work correctly. Contractors sometimes tend to schedule activities independently, at the earliest time they can start, and then tie the

activity's early finish time to the contract completion rather than another activity. Contractor's should instead attempt to tie activities to each other whenever possible. Even when a group of related activities have been completed it is best to have the sequence move to another group of related activities rather than to the end of the job. The schedule should reflect an interrelated work flow and not a series of parallel activities whose finish dates are tied to the project's completion.

6.3 Points to Remember About CPM Networks

Most contracts require that some sort of project schedule be kept, but they are not clear on the approval process. The contractor should be aware of the legal significance of the owner's approval of the schedule. If the owner tries to refute a schedule as not feasible, the fact that the owner approved it can weigh heavily in the contractor's favor. In some cases the owner only acknowledges receipt of the schedule without approving it in order to avoid this responsibility for acceptance. However, if the owner has a contractual duty to accept the chart then he also has a duty to express any objections he may have. If the contractor submits a schedule and the owner

expresses his objections, then the schedule should be revised and resubmitted.

The critical path may shift during the course of the work due to change orders, delays , or other variations in the progress of the work. The schedule should be updated to reflect these variations, lest the original schedule become of little value in completion of the work. When the critical path changes, the rationale should be recorded. Sometimes, when cases reach the courts years after the fact, the CPM shows that the path shifted but no one can remember why.

The owner may choose to keep his own CPM or other progress schedule. This may not become known until a dispute arises, so the contractor should be aware that there may be a progress schedule being checked by the owner. A progress schedule may be mounted defensively as well as offensively. Either side can construct a chart after the fact purporting to show that its position is correct. Thus, it is advisable to require periodic checkoffs. A "new" schedule cannot materialize overnight when both parties are regularly checking off and revising the schedule as a mutual effort.

There are sceduling consultants who can be called upon to analyze the schedules when disputes arise, or to give advice during the course of the work. On very

complex projects, it is a good idea to utilize the services of these consultants whenever possible.

Any network is only as good as the logic used to set up the critical path(s). These schedules should not be regarded as infallible. They can be changed and revised as the job progresses to give the clearest possible picture of what has happened on the job and why. When disputes reach the courtroom a more succinct summary of job progress should be made. The schedule should be condensed into an effective summary so that those not familiar with construction or scheduling techniques will be able to understand the case being presented.

CHAPTER VII

CONCLUSION

7.1 Conclusions

There has been reluctance to use CPM network analysis as evidence of delays and disruptions. Major concerns were possible technical errors in the system or a failure of the system to portray the work done in a realistic fashion. This may have been due to the fact that early presentations had CPM network analysis based on speculation, inferences, or innuendos rather than hard documented facts. Thus, the usefulness of a CPM network schedule is dependent on four factors:

1. The soundness of the CPM schedule itself. This requires proof of the reasonableness and feasibility of the schedule so as to show that on a theoretical basis the scheduling was sound.

2. The extent to which the delays can be established by substantial evidence. The basic records and evidence available to the claimant showing the underlying causes of delay or disruption must be substantiated.

3. The nature of any changes to the CPM network made during the claim analysis process. The claimant must accurately and with specificity have analyzed the network schedule in making his presentation.

4. There must be some indication that the work sequence shown was the only one possible or a reasonable one by which the work could be completed on time.

The use of CPM schedules to prove or disprove one's right to time extensions, to show one's right for

additional payments or possibly to show a reduction in payments is a method whose time has come. Many thousands of dollars can be spent during construction contract disputes to set up a CPM schedule and subsequently impact them with delays and changes in scope so that the contractor can prove the effects on the duration and cost of the work. However, if the schedule is not technically or factually accurate, this expense can be wasted.

When it comes to establishing a claim involving owner delays or interference the contractor has a large burden in proving entitlement. Failure to correlate the owner caused problems directly with the impact may prove fatal to the claim. The contractor needs to have a proper schedule depicting anticipated construction progress and actual construction delays. The particular method employed is as important as having a logical, ordered method for the presentation.

The contractor who seeks to successfully prove a claim must have a reasonably planned schedule that shows the interrelationships of the major trades working on the project and the chain of activities which dictate the final project completion date. Boards and courts are consistently stating that bar charts or other similar schedules are not satisfactory because of their inability to show the interrelationships of activities.

By comparing the CPM schedule with the contractor's actual performance the court or board can determine if the contractor was affected by actions of the owner.

Courts and boards are further realizing that the sheer number of owner changes will not justify a time extension. They point out that a proper CPM schedule will give the contractor the flexibility to depict and manage contract changes. Without a properly maintained schedule the contractor is not able to do this (6:32).

In any event, it is becoming apparent that courts and boards are going to be looking more and more to CPM networks or other schedules which have the ability to show activity relationships when trying to solve disputes that involve contract time problems. Even if the dispute never gets to that point, the contractor who has a network schedule may be able to convince the owner's representatives of the reasonableness of his claim and thus save himself the time and cost of a legal battle.

7.2 Recommendations

To be more successful when processing modifications and evaluating contractor impact claims, the Navy should look toward developing better methods for estimating the impact of these changes or disruptions to the contractor's work. The Naval Facilities

Engineering Command (NAVFAC) should look at developing logical methods and techniques for preparing accurate time estimates so that their representatives will enter negotiations properly prepared. This will enhance the prospect of coming up with a fair and reasonable agreement, thus reducing the number of claims that the government must handle.

Currently the Navy has no standard guidelines that can be used for the evaluation of the impact of a change or disruption on the contractor's progress schedule. The result is a lack of uniformity in the NAVFAC community when reviewing contractor requests or claims for time extensions. Standard procedures for reviewing network schedules should be implemented so that both the government and contractor representatives will be aware of their documentation responsibilities in regard to time extension requests.

For the identification of impact, a network schedule which employs CPM is the most desirable. Bar charts can be used on small, routine, and straight-forward projects where the presence or absence of impact will probably be fairly evident. However, the use of a bar chart on larger projects will usually require the government representatives convert it into a network schedule prior to a proper impact evaluation. Thus, it is recommended that the regular employment of

network schedules on larger, more complicated construction contracts be examined by NAVFAC. In addition, it may be beneficial to require the use of network analysis techniques for any significant time extension requests (e.g. those that are greater than seven days) on those same contracts.

In order to determine the possible benefit and cost effectiveness of network analysis techniques in the resolution of modifications or claims involving time impact determinations it is recommended that NAVFAC examine the possibility of further developing and using the techniques outlined in this paper. This could be done on a limited basis with one of the Engineering Field Divisions. Following this study a more complete picture would be available on the role network analysis techniques could play in the resolution of claims involving damages due to time impacts.

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